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磁気ノズル中径方向拡散の抑制によるヘリコンスラスターの性能向上

Performance improvement of a helicon plasma thruster by inhibiting a cross-field diffusion in a magnetic nozzle

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Over the past few decades, various electric propulsion devices such as ion gridded thrusters and hall thrusters have been developed ans successfully tested in space. The new concept of electrodeless plasma thruster called "HELICON THRUSTER" is recently investigated theoretically [1,2] and experimentally [3,4]. The helicon thruster has a simple structure consisting of an insulator source cavity wound by a rf antenna and a magnetic nozzle, which can be provided by solenoids and/or permanent magnets. Some of the theories and experiments have suggested that the axial plasma momentum can be increased by a magnetic nozzle due to a presence of a spontaneous azimuthal plasma current (mainly electron diamagnetic drift current) and the radial magnetic field. It would be important to understand the plasma flow dynamics in the magnetic nozzle, which appears to be more complex than people thought because of the presence of the magnetic field, heating source, physical boundaries, non-Maxwellian electron energy distribution [5], and so on.

Here laboratory experiment of a helicon plasma thruster is established to control only the plasma cross-field diffusion in a rapidly-divergent magnetic nozzle, while maintaining a constant plasma injection into the magnetic nozzle. Measurement of the plasma density shows that the unchanged plasma density within the source cavity while increasing the density in the magnetic nozzle when increasing the solenoid current (not shown here). The radial measurements suggest the cross field diffusion can be inhibited by the field strength and yield the higher plasma density in the nozzle. The thrust is equal in magnitude and opposite in direction to the force imparted to the thruster structure. The force components imparted to axial (T_s) and radial (T_w) source boundaries and to the magnetic nozzle (T_B) are independently measured with changing the cross-field diffusion and the resultant plasma flow in the magnetic nozzle. The results show a constant force to the axial boundary, a negligible force to the radial boundary, and an increasing force to the magnetic nozzle, with an increasing the field strength of the magnetic nozzle. It is found that the measured thrust component T_B is approaching the theoretical limit of the electron diamagnetic-induced thrust derived from an ideal magnetic nozzle approximation. The total thrust T_{total} corresponding to $T_s + T_w + T_B$ also increases simultaneously with increasing the T_B components.

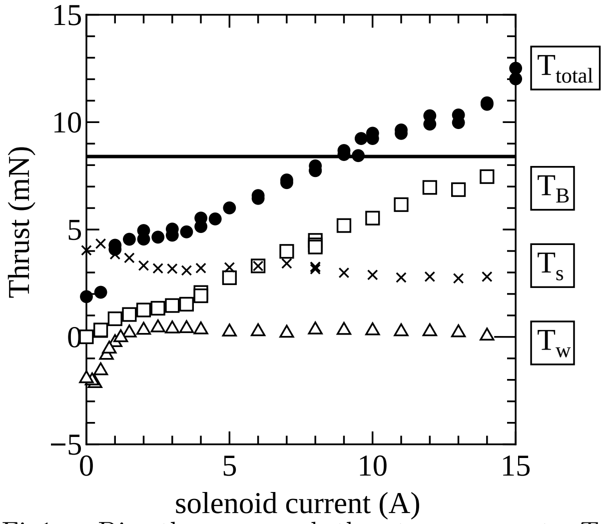

Fig1. Directly measured thrust components T_s (crosses), T_w (open triangles), T_B (open squares), and T_{total} (filled circles) as a function of the solenoid current, together with the theoretical limit of T_B (solid line) for the presently measured electron pressure near the source exit.

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